

Nuclear Science Research Division

Astro-Glaciology Laboratory

1. Abstract

Our Astro-Glaciology Laboratory promotes both experimental and theoretical studies to open up the new interdisciplinary research field of astro-glaciology, which combines astrophysics, astrochemistry, glaciology, and climate science.

On the experimental side, we measure isotopic and ionic concentrations in ice cores drilled at Dome Fuji station, Antarctica, in collaboration with the National Institute of Polar Research (NIPR, Tokyo). Here, the ice cores are time capsules which preserve atmospheric information of the past. In particular, the ice cores obtained around the Dome Fuji site are very unique, because they contain much more information on the stratosphere than any other ice cores obtained from elsewhere on Earth. This means that we have significant advantages in using Dome Fuji ice cores if we wish to study the Universe, since UV photons, gamma-rays, and high energy protons emitted by astronomical phenomena affect the stratosphere.

Our principal aim is thus to acquire and interpret information preserved in ice cores regarding:

- Signatures of past volcanic eruptions and solar cycles;
- Relationship between climate change and solar activity;
- Traces of past supernovae in our galaxy, in order to understand better the rate of galactic supernova explosions.

Moreover, we are promoting experimental projects on:

- Development of “RIKEN-LMS” (Laser Melting Sampler) for analyzing ice cores with high depth resolution;
- Development of precise analytical techniques of high sensitivity for analyzing ice cores;
- The application of analytical methods for measuring isotopes in ice cores to archaeological artifacts;
- The evolution of molecules in space;

On the theoretical side, we are simulating numerically:

- Chemical effects of giant solar flares and supernovae on the Earth’s atmosphere;
- The explosive and the *r*-process nucleosynthesis in core-collapse supernovae;

Combining our experimental evidence and theoretical simulations, we are promoting the researches mentioned above. These all will contribute to understanding relationships between the Universe and Earth. In particular, climate change is the most critical issue facing the world in the 21st century. It is also emphasized that the frequency of supernova explosions in our galaxy has not yet been fully understood, and it is the key to understand the *r*-process nucleosynthesis.

Members

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List of Publications & Presentations**Publications****[Original Papers]**

- Y. Motizuki, Y. Nakai, K. Takahashi, Y. V. Sahoo, J. Hirose, M. Yumoto, M. Maruyama, M. Sakashita, K. Kase, S. Wada, H. Motoyama, and Y. Yano, "A novel laser melting sampler for discrete, sub-centimeter depth-resolved analyses of stable water isotopes in ice cores," *J. Glaciol.*, published online (2023). DOI: 10.1017/jog.2023.52 .
- Y. Nakai, W. M. C. Sameera, K. Furuya, H. Hidaka, A. Ishibashi, and N. Watanabe, "Methanol formation through reaction of low-energy CH_3^+ ions with an amorphous solid water surface at low temperature," *Astrophys. J.* **953**, 162 (2023). DOI: 10.3847/1538-4357/accf95 .
- E. R. Thomas, D. O. Vladimirova, D. R. Tetzner, B. D. Emanuelsson, N. Chellman, D. A. Dixon, H. Goosse, M. M. Grieman, A. C. F. King, M. Sigl, D. Udy, T. R. Vance, D. A. Winski, V. H. L. Winton, N. A. N. Bertler, A. Hori, C. M. Laluraj, J. R. McConnell, Y. Motizuki, H. Motoyama, Y. Nakai, K. Takahashi, F. Schwanck, J. C. Simões, F. G. L. Lindau, M. Severi, R. Traversi, S. Wauthy, C. Xiao, J. Yang, and E. Mosely-Thompson, "Ice core chemistry database, an Antarctic compilation of sodium and sulfate records spanning the past 2000 years," *Earth Syst. Sci. Data* **15**, 2517–2532 (2023). DOI: 10.5194/essd-15-2517-2023 .
- J. M. Rés-Vicente, J. A. Cuchí-Oterino, T. Minami, K. Takahashi, J. Martín-Gil, J. I. Lorenzo-Lizalde, and P. Martín-Ramos, "Use of cinnabar in funerary practices in the Central Pyrenees, Analysis of pigments on bones from the prehistoric burial of the Cueva de la Sierra cave in Campodarbe (Huesca, Spain)," *J. Archaeol. Sci. Rep.* **48**, 103849 (2023). DOI: 10.1016/j.jasrep.2023.103849 .

[Proceedings]

南武志, 高橋和也, 「丹波丸山 6 号墳より出土した赤色顔料—水銀朱—の産地推定」, 公益財団法人京都府埋蔵文化財調査研究センター, 京都府遺跡調査報告集 第 188 冊, 84–86 (2023).

Presentations**[International Conferences/Workshops]**

- Y. Nakai, "Reactions through the irradiation of an ice surface with low-energy molecular ions at low temperatures," Third Laboratory Astrophysics Workshop (ICE2024), Kapaa, Kauai, Hawaii, USA, February 18–22, 2024.
- Y. Motizuki, Y. Nakai, K. Takahashi, Yu Vin Sahoo, J. Hirose, M. Yumoto, M. Maruyama, M. Sakashita, K. Kase, S. Wada, H. Motoyama, and Y. Yano, "A novel laser melting sampler for discrete, sub-centimeter depth-resolved analyses of stable water isotopes in ice cores," The 14th Symposium on Polar Science, Tachikawa, Japan, November 14–17, 2023.
- Y. Nakai, W. M. C. Sameera, K. Furuya, H. Hidaka, A. Ishibashi, and N. Watanabe, "Methanol production through irradiation of low-energy CH_3^+ ions on an ice surface at low temperature," Workshop on Interstellar Matter 2023, Sapporo, Japan, November 8–10, 2023.
- M. Tsuge, A. Miyazaki, N. Sie, W. M. C. Sameera, Y. Nakai, T. Hama, H. Hidaka, A. Kouchi, and N. Watanabe, "Visible light induced photodesorption of hydroxyl radicals from amorphous solid water," The 15th International Conference on the Physics and Chemistry of Ice, Sapporo, Japan, September 3–8, 2023.
- Y. Nakai, W. M. C. Sameera, K. Furuya, H. Hidaka, A. Ishibashi, and N. Watanabe, "Methanol production through the impingement of low-energy CH_3^+ ions onto an ice surface at low temperature," The 15th International Conference on the Physics and Chemistry of Ice, Sapporo, Japan, September 3–8, 2023.
- N. Watanabe (paper), Y. Nakai, W. M. C. Sameera, K. Furuya, H. Hidaka, and A. Ishibashi, "Methanol production via irradiation of low-energy CH_3^+ ions on an ASW surface," 2023 Kavli-IAU Astrochemistry Symposium. Astrochemistry VIII—From the First Galaxies to the Formation of Habitable Worlds, Traverse, Michigan, USA, July 10–14, 2023.
- A. Miyazaki, M. Tsuge, H. Hidaka, Y. Nakai, and N. Watanabe, "Determination of the activation energy for diffusion of OH radicals on water ice," 38th Symposium on Chemical Kinetics and Dynamics, Fukuoka, Japan, June 7–9, 2023.

[Domestic Conferences/Workshops]

- 山脇鷹也 (ポスター), 勝田哲, 藤原均, 三好勉信, 三好由純, 望月優子, 中澤知洋, 中島基樹, 信川久実子, 大塚雄一, 品川裕之, 新堀淳樹, 塩川和夫, 惣宇利卓弥, 丹波翼, 田代信, 和田有希, 「X 線天文衛星が捉えた 2022 年トンガ海底火山大噴火による超高層大気の密度変動」, 第 23 回高宇連研究会, 京都市 (現地開催+オンライン), 2024 年 3 月 27–29 日.
- 望月優子, 「科研費基盤 A『新開発 RIKEN-LMS で挑む南極深層アイスコアからの天文情報抽出』の紹介」, ドームふじ研究集会+第 3 期ドーム深層掘削会合, 立川市 (現地開催+オンライン), 2024 年 3 月 26–27 日.
- 望月優子, 「"Ice-Core Astro-Factory" 計画, 南極アイスコア中の超新星痕跡同定への取り組み」, 第 10 回超新星ニュートリノ研究会, 岡山市, 2024 年 2 月 29 日–3 月 1 日.
- 望月優子 (招待講演), 「化学分析誤差を誤差伝播則から突き詰める～南極アイスコアデータから抽出される太陽活動周期を例にして～」, お茶の水女子大学理学部物理学教室談話会, 文京区, 2023 年 12 月 6 日.
- Sie Ni-En, 柘植雅士, 中井陽一, Sameera W. M. C., 渡部直樹, "Photodesorption of hydroxyl radicals from ice surface induced by visible photons," 原子衝突学会第 48 回年会, 目黒区, 2023 年 11 月 25–26 日.
- 中井陽一, 「複雑有機分子生成への気相分子イオンと氷星間塵表面の協働, 実験からのアプローチ」, 学術変革領域研究 (A) 次世代アストロケミストリー第 2 回 気相実験ワークショップ, 東京都, 2023 年 11 月 24 日.
- 柘植雅士, 北島謙生, 中井陽一, Sameera W. M. C., 渡部直樹, 「極低温 H_2O 氷における負電荷伝導」, 第 17 回分子科学討論会, 豊中市, 2023 年 9 月 12–15 日.

望月優子 (招待講演), 「南極アイスコアからさぐる地球と宇宙の歴史」, 埼玉県高等学校中堅教諭等資質向上研修 (理科), 行田市 (オンライン), 2023 年 8 月 17 日.

望月優子 (招待講演), 「“RIKEN Ice Core Factory” 計画と理論研究により目指すもの」, 宇宙物理と超高層大気物理の融合研究会, さいたま市, 2023 年 6 月 30 日.

Press Releases

望月優子, 中井陽一, 和田智之, 矢野安重, 「レーザー融解によるアイスコアの微細試料採取装置の開発—アイスコア科学の超精密化に進展をもたらす技術革新—」, 2023 年 9 月 19 日, https://www.riken.jp/press/2023/20230919_2/index.html.

Yuko Motizuki, Yoichi Nakai, Satoshi Wada, Yasushige Yano, “Laser-based ice-core sampling for studying climate change,” September 20, 2023, https://www.riken.jp/en/news_pubs/research_news/pr/2023/20230919_2/.

Yuko Motizuki, “Shining a light on climate change over a million years,” RIKEN Research Winter 2023, 16, https://www.riken.jp/medialibrary/riken/pr/publications/riken_research/2023/rr202312.pdf.

Asian Scientist Magazine, “Lasers Help Probe Past Climates In Ice Cores,” October 30, 2023, <https://www.asianscientist.com/2023/10/general/lasers-help-probe-past-climates-in-ice-cores/>.

日本経済新聞, 「理化学研究所, 南極の氷分析新装置 20 万年前の気候把握」, 2023 年 9 月 29 日, <https://www.nikkei.com/article/DGXZQ0UC21D4Y0R20C23A9000000/>.

オプトロニクスオンライン, 「理研ら, アイスコアの微細試料採取装置を開発」, 2023 年 9 月 20 日, <https://optronics-media.com/news/20230920/83456/>.